National Aeronautics and Space Administration

Status of Research at GSFC SRT and Plans for Version 6

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AIRS Science Team

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Pasadena, California

Current Status

- Improvements made to surface retrieval step since Version 5 have been shown previously

  AIRS NET-Meeting, March 13, 2008

  SPIE Conference, March 18, 2008

- Methodology and results also shown in 12 page SPIE extended abstract

  Available electronically

- Further improvements (Version 5.13) have been made since NET-Meeting (Version 5.12)

Outline of the Talk

Overview of changes from 5.0 to 5.12

Additional changes from 5.12 to 5.13

Comparison of results of 5.0, 5.12, and 5.13

Comparison of Version 5.13 results with metrics

Plans for future improvements

Steps in Version 5 Level 2 and Version 5.12

MIT AMSU Retrieval

Cloudy regression gives X^{CR}

AMSU Retrieval using X^{CR} gives $X^{microwave} = X^0$ (now solve for $T(p)$, ε_ν only - not T_s)

Determine $\hat{R}_i^0, \alpha^0, P_c{}^0$ using X^0

Determine X^{reg} from $\hat{R}_i^0$

AMSU retrieval using X^{reg} gives X^1 (now solve for $T(p)$, ε_ν only - not T_s)

Determine $\hat{R}_i{}^1$ using X^1

Physical retrieval using $\hat{R}_i{}^1$ and X^1 gives X^{PHYS}

AMSU retrieval using X^{PHYS} gives X^{test}

$\hat{R}_i{}^2$ determined from X^{PHYS}

Physical retrieval using $\hat{R}_i{}^2$ gives X^{final}

Select X^0 or X^{final}

Clouds, OLR determined from X^0 or X^{final}

Generate error estimates δX

Do QC

Steps Modified in Version 5.12

Changes Made to Steps in the Physical Retrieval in Version 5.12

First Pass

Initialize $\rho(\nu)$ - new step

Solve for surface parameters - $T_s, \varepsilon_{SW}(\nu), \rho_{SW}(\nu)$

Solve for T(p) and also update $T_s, \varepsilon_{SW}(\nu), \rho_{SW}(\nu)$

Solve for q(p)

Solve for $\varepsilon_{LW}(\nu)$ – new step

Solve for O_3(p)

Second Pass

Initialize ρ_ν - new step

Solve for surface parameters - $T_s, \varepsilon_{SW}(\nu), \rho_{SW}(\nu)$

Solve for T(p) and also update $T_s, \varepsilon_{SW}(\nu), \rho_{SW}(\nu)$

Solve for $\varepsilon_{LW}(\nu)$ – new step

Steps Modified in Version 5.12

Version 5.12 Changes to Surface Parameter Retrieval Channel Set and $F_i(\nu)$

Version 5 - solves for $T_s, \varepsilon_{LW}(\nu), \varepsilon_{SW}(\nu), \rho_{SW}(\nu)$ simultaneously

- 15 channels between 758 cm^{-1} and 1228 cm^{-1}
- 10 channels between 2456 cm^{-1} and 2658 cm^{-1}
- 3 LW $F_i(\nu)$, 1 SW $F_i(\nu)$, 1 SW $G_i(\nu)$

Version 5.12 - solves for $T_s, \varepsilon_{SW}(\nu), \rho_{SW}(\nu)$ first

- 57 channels between 2395 cm^{-1} and 2660 cm^{-1}
- 2 SW $F_i(\nu)$, 2 SW $G_i(\nu)$

Using only shortwave channels to solve for T_s lessens sensitivity to cloud clearing errors

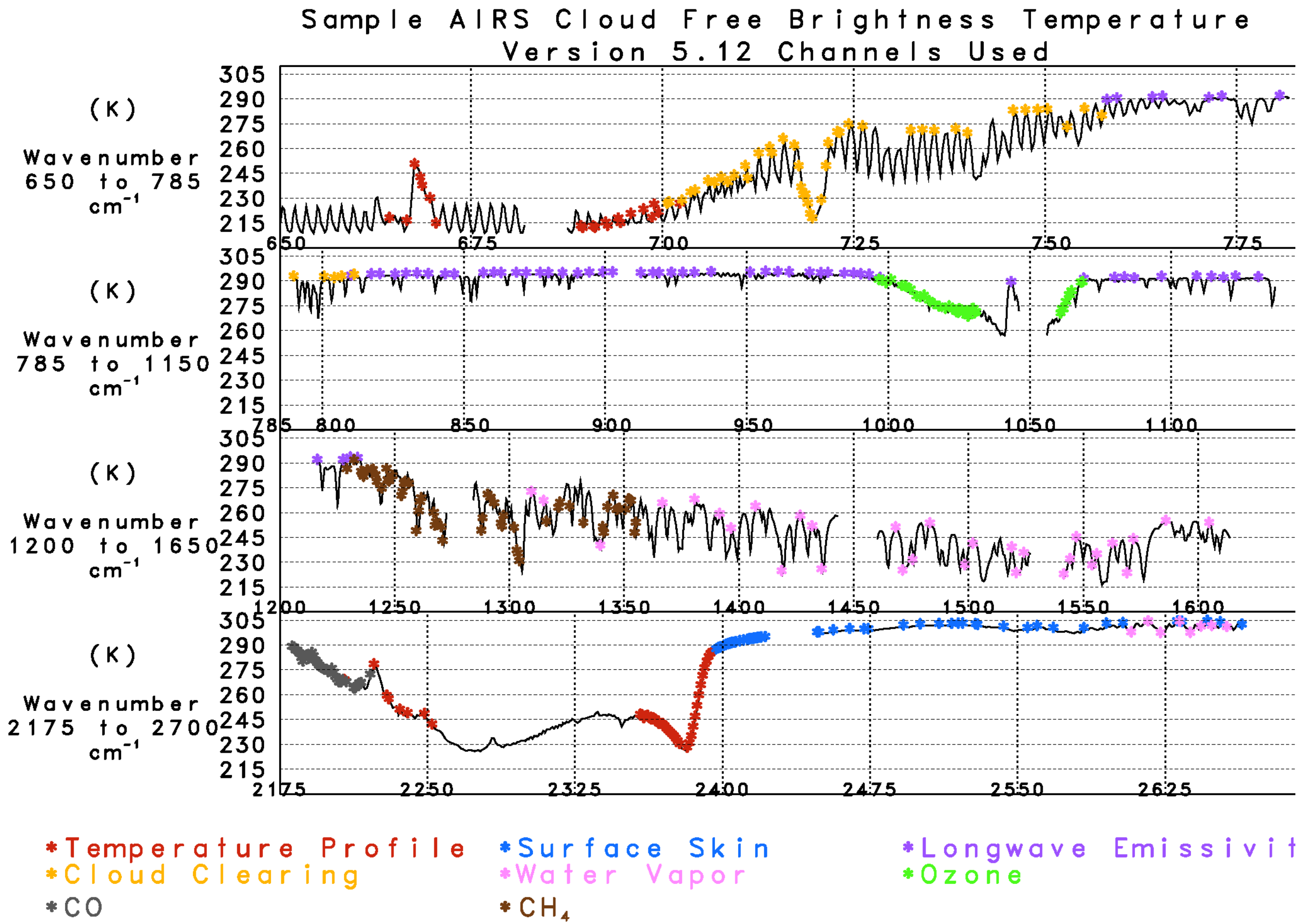
Version 5.12 T(p) step now includes the 57 shortwave T_s channels

- Updates surface parameters as well as solve for T(p)
- Does not need $\varepsilon_{LW}(\nu)$

$\varepsilon_{LW}(\nu)$ is solved for in Version 5.12 in a new step after T(p), q(p) are solved for

ε_{LW} step keeps T_s, T(p), q(p) as fixed

- 70 channels between 758 cm^{-1} and 1234 cm^{-1}
- 3 LW $F_i(\nu)$
- This step is very stable - probably can solve for more LW $F_i(\nu)$


Sample AIRS Cloud Free Brightness Temperature
Version 5.12 Channels Used
(K)
Wavenumber 650 to 785 cm-1
(K)
Wavenumber 785 to 1150 cm-1
(K)
Wavenumber 1200 to 1650 cm-1
(K)
Wavenumber 2175 to 2700 cm-1
305
290
275
260
245
230
215
650 675 700 725 750 775
785 800 850 900 950 1000 1050 1100
1200 1250 1300 1350 1400 1450 1500 1550 1600
2175 2250 2325 2400 2475 2550 2625
*Temperature Profile
*Surface Skin
*Longwave Emissivit
*Cloud Clearing
*Water Vapor
*Ozone
*CO
*CH4

Changes Made from Version 5.12 to Version 5.13

Changes made only in channels used

Previous spectrum showing Version 5.12 channels was not strictly correct

Spectrum shows no cloud clearing 15 μm channels (yellow) with $\nu < 701$ cm^{-1}

Spectrum shows no 15 μm temperature sounding channels with $\nu > 701$ cm^{-1}

This is the way it should be, but

- Version 5.12 had 11 cloud clearing channels with $\nu < 701$ cm^{-1}
- Version 5.12 had 13 channels used for both cloud clearing and T(p) with $\nu < 713$ cm^{-1}

Version 5.13 removed all cloud clearing channels with $\nu < 701$ cm^{-1} all T(p) channels with $\nu < 713$ cm^{-1}

Version 5.13 also modified frequencies of 4 other cloud clearing channels between 743 cm^{-1} and 760 cm^{-1}

There were no other changes between Version 5.12 and Version 5.13

Assessment of Potential Improvements over Ocean

SST is reasonably well known - use ECMWF analysis as truth

Compare quality controlled SST with ECMWF

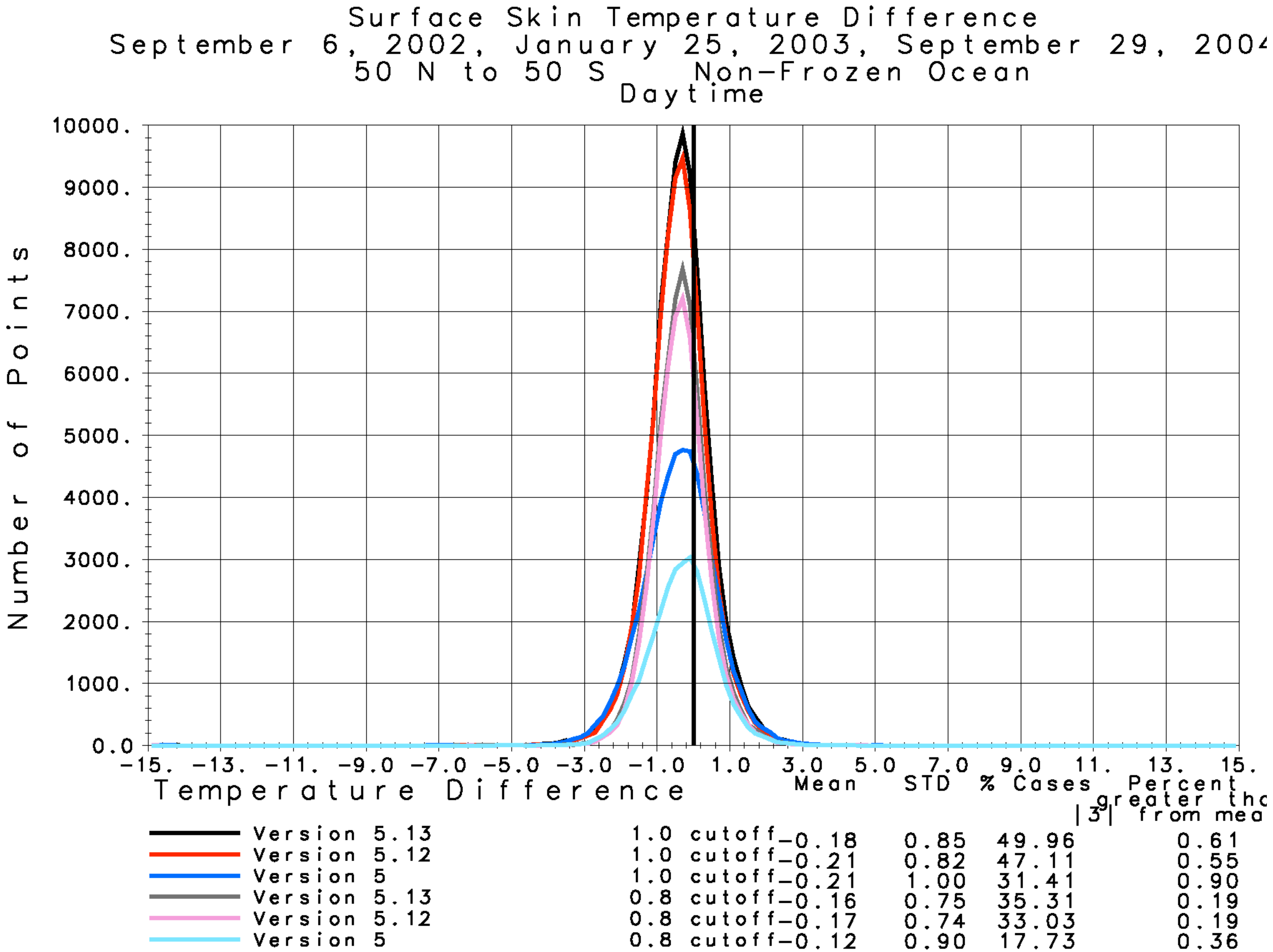
Improvements in SST are indicated by lower standard deviation from truth and % outliers, with increased yield

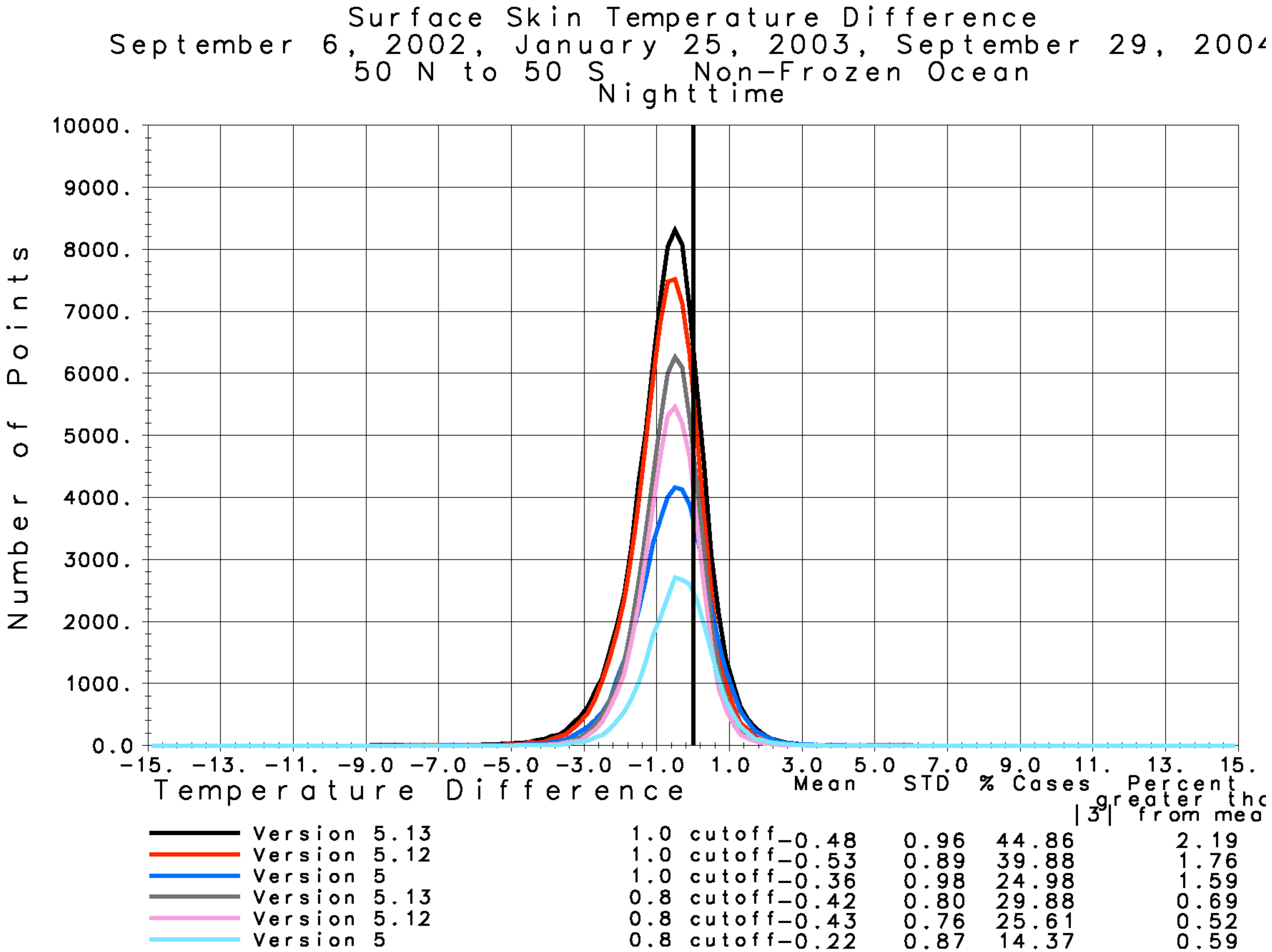
Spectral emissivity is reasonably well known - Masuda model

- Depends on satellite zenith angle and wind speed
- Emissivity does not change significantly from day to night

Improvements in retrieved emissivity are indicated by

- Better agreement with Masuda
- Lower standard deviation of angular mean surface emissivity
- Smaller day/night differences of retrieved angular mean surface emissivity


Surface Skin Temperature Difference
September 6, 2002, January 25, 2003, September 29, 2004
50 N to 50 S Non-Frozen Ocean
Daytime
Number of Points
10000.
9000.
8000.
7000.
6000.
5000.
4000.
3000.
2000.
1000.
0.0
-15.
-13.
-11.
-9.0
-7.0
-5.0
-3.0
-1.0
1.0
3.0
5.0
7.0
9.0
11.
13.
15.
Temperature Difference
Mean
STD
% Cases
Percent greater than |3| from mean
Version 5.13 1.0 cutoff -0.18 0.85 49.96 0.61
Version 5.12 1.0 cutoff -0.21 0.82 47.11 0.55
Version 5 1.0 cutoff -0.21 1.00 31.41 0.90
Version 5.13 0.8 cutoff -0.16 0.75 35.31 0.19
Version 5.12 0.8 cutoff -0.17 0.74 33.03 0.19
Version 5 0.8 cutoff -0.12 0.90 17.73 0.36



Surface Skin Temperature Difference
September 6, 2002, January 25, 2003, September 29, 2004
50 N to 50 S Non-Frozen Ocean
Nighttime
Number of Points
10000.
9000.
8000.
7000.
6000.
5000.
4000.
3000.
2000.
1000.
0.0
-15.
-13.
-11.
-9.0
-7.0
-5.0
-3.0
-1.0
1.0
3.0
5.0
7.0
9.0
11.
13.
15.
Temperature Difference
Mean STD % Cases Percent greater than |3| from mean
Version 5.13 1.0 cutoff -0.48 0.96 44.86 2.19
Version 5.12 1.0 cutoff -0.53 0.89 39.88 1.76
Version 5 1.0 cutoff -0.36 0.98 24.98 1.59
Version 5.13 0.8 cutoff -0.42 0.80 29.88 0.69
Version 5.12 0.8 cutoff -0.43 0.76 25.61 0.52
Version 5 0.8 cutoff -0.22 0.87 14.37 0.59

Metrics for Improved Daytime Ocean Skin Temperature

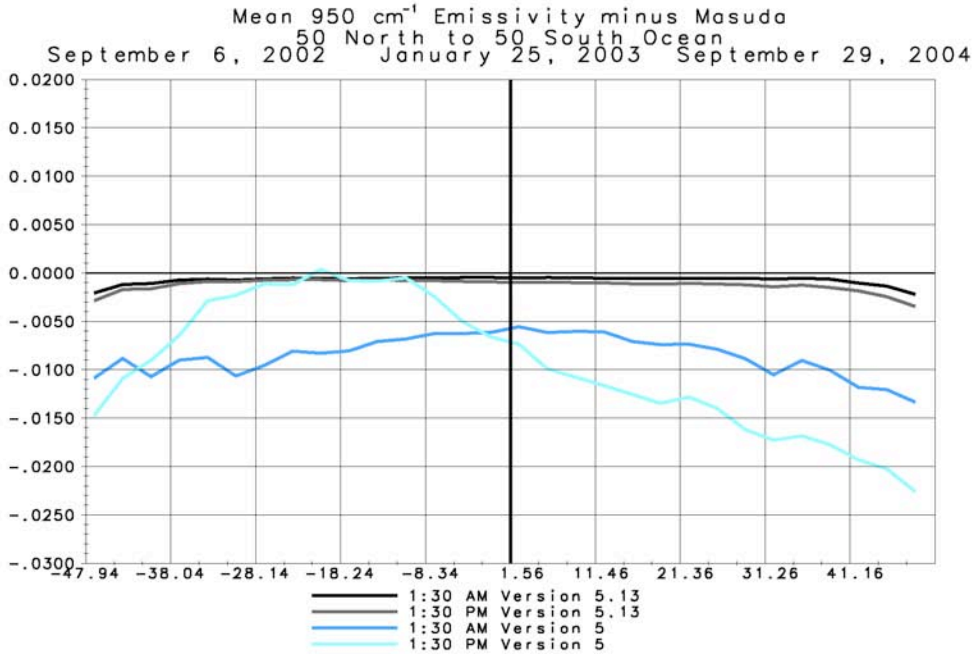
		% Accepted	% Outliers	Bias (K) vs. ECMWF
Version 5	QC = 0	18%	0.36%	-.12
Version 5	QC = 0, 1	31%	0.90%	-.21
Version 5.13	QC = 0	30%	0.19%	-.19
Version 5.13	QC = 0, 1	50%	0.76%	-.22
Version 6 Goal	QC = 0	30%	0.50%	-.15
Version 6 Goal	QC = 0, 1	50%	1.00%	-.20

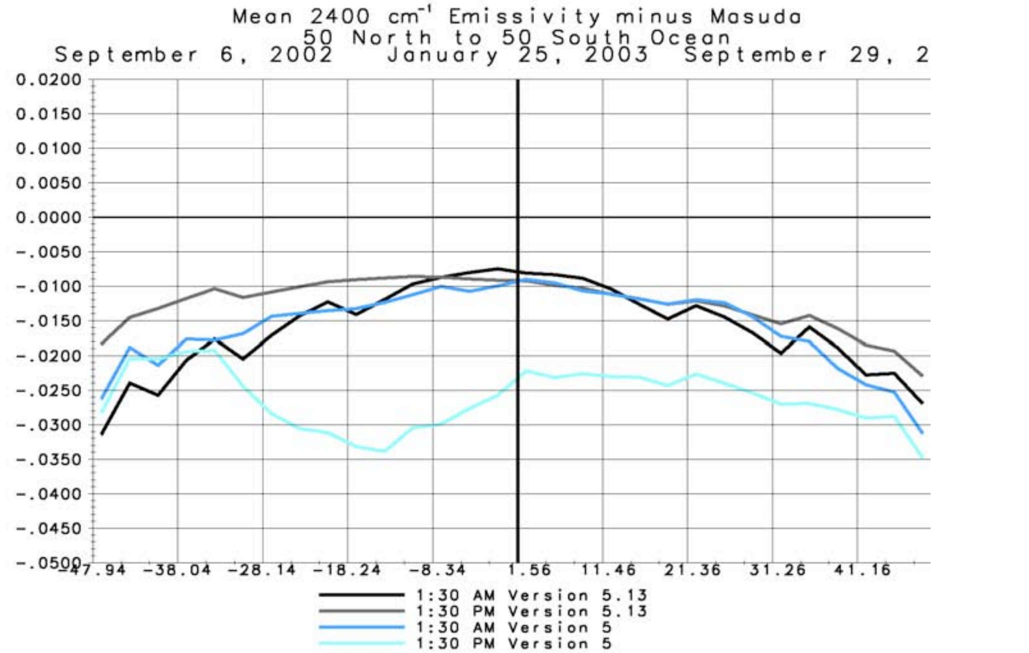
Version 5.13 performance exceeds goals for outliers
Version 5.13 performance essentially meets goals for biases

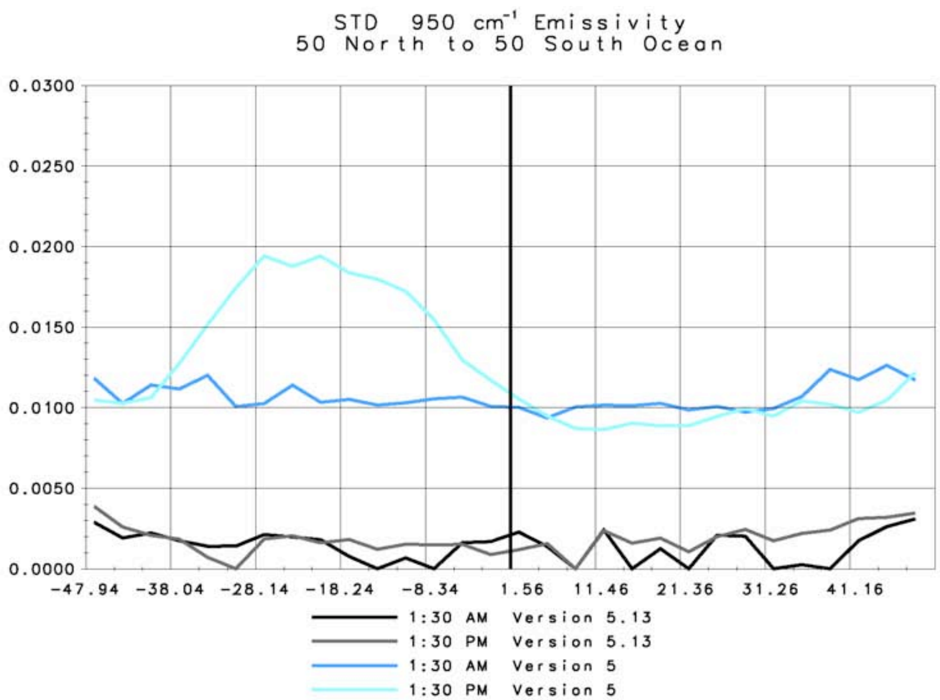
Metrics for Improved Nighttime Ocean Skin Temperature

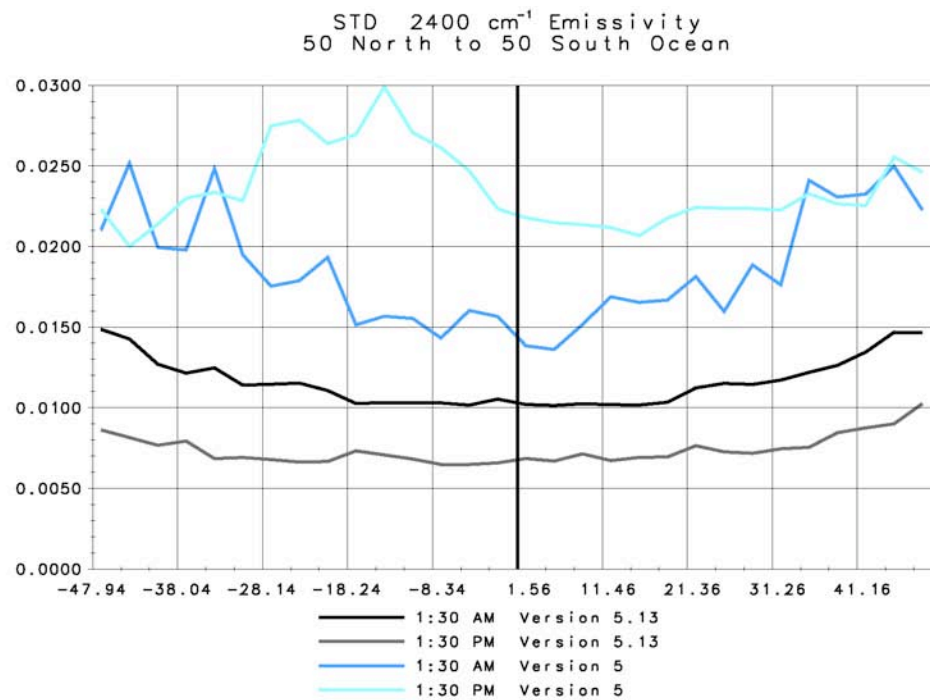
		% Accepted	% Outliers	Bias (K) vs. ECMWF
Version 5	QC = 0	14%	0.59%	-.22
Version 5	QC = 0, 1	25%	1.59%	-.36
Version 5.13	QC = 0	25%	0.63%	-.44
Version 5.13	QC = 0, 1	40%	1.95%	-.49
Version 6 Goal	QC = 0	25%	1.00%	-.25
Version 6 Goal	QC = 0, 1	40%	2.00%	-.30

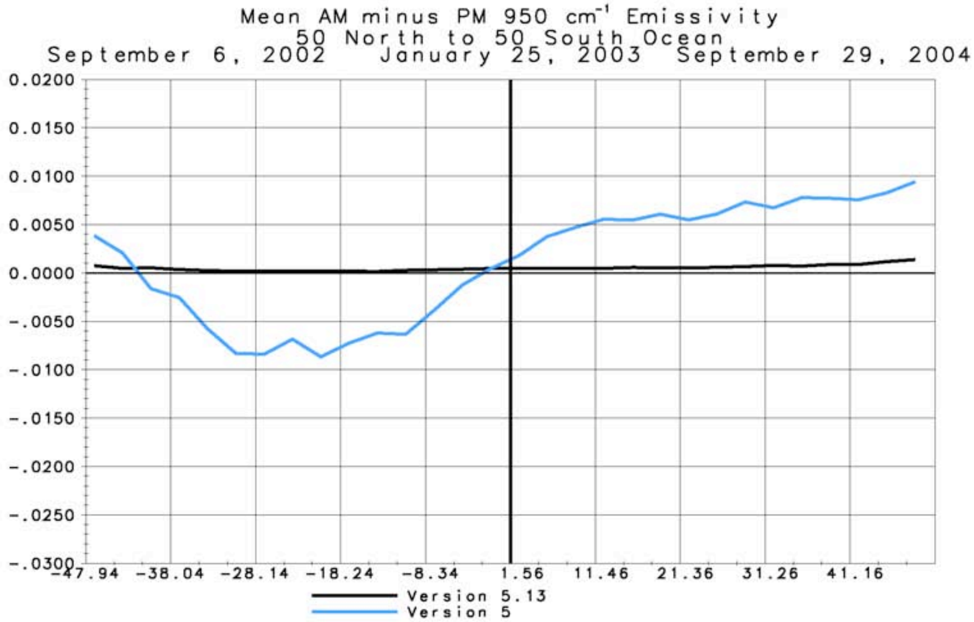
Version 5.13 performance exceeds goals for outliers
Version 5.13 performance does not meet goals for biases


Mean 950 cm^{-1} Emissivity minus Masuda
50 North to 50 South Ocean
September 6, 2002 January 25, 2003 September 29, 2004
0.0200
0.0150
0.0100
0.0050
0.0000
-.0050
-.0100
-.0150
-.0200
-.0250
-.0300
-47.94 -38.04 -28.14 -18.24 -8.34 1.56 11.46 21.36 31.26 41.16
1:30 AM Version 5.13
1:30 PM Version 5.13
1:30 AM Version 5
1:30 PM Version 5

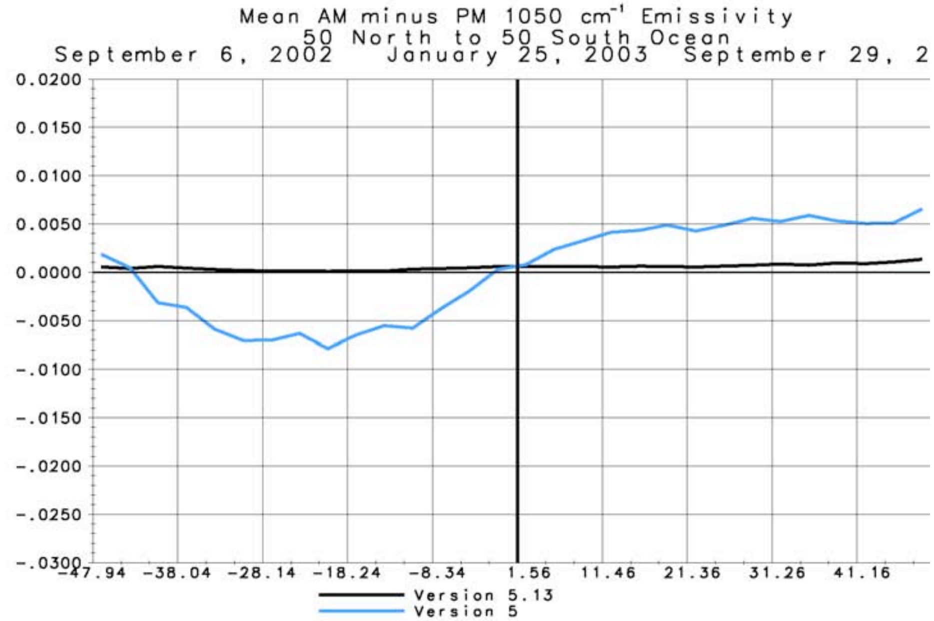

Mean 2400 cm^{-1} Emissivity minus Masuda
50 North to 50 South Ocean
September 6, 2002 January 25, 2003 September 29, 2
0.0200
0.0150
0.0100
0.0050
0.0000
-.0050
-.0100
-.0150
-.0200
-.0250
-.0300
-.0350
-.0400
-.0450
-.0500
-47.94 -38.04 -28.14 -18.24 -8.34 1.56 11.46 21.36 31.26 41.16
1:30 AM Version 5.13
1:30 PM Version 5.13
1:30 AM Version 5
1:30 PM Version 5


STD 950 cm^{-1} Emissivity
50 North to 50 South Ocean
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
-47.94 -38.04 -28.14 -18.24 -8.34 1.56 11.46 21.36 31.26 41.16
1:30 AM Version 5.13
1:30 PM Version 5.13
1:30 AM Version 5
1:30 PM Version 5

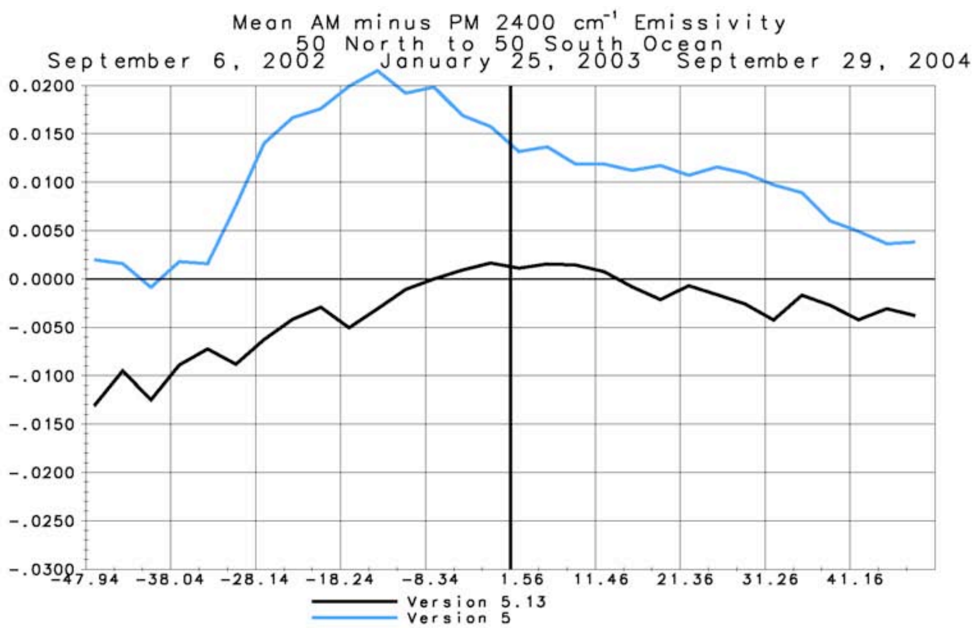

STD 2400 cm^{-1} Emissivity
50 North to 50 South Ocean
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
-47.94 -38.04 -28.14 -18.24 -8.34 1.56 11.46 21.36 31.26 41.16
1:30 AM Version 5.13
1:30 PM Version 5.13
1:30 AM Version 5
1:30 PM Version 5



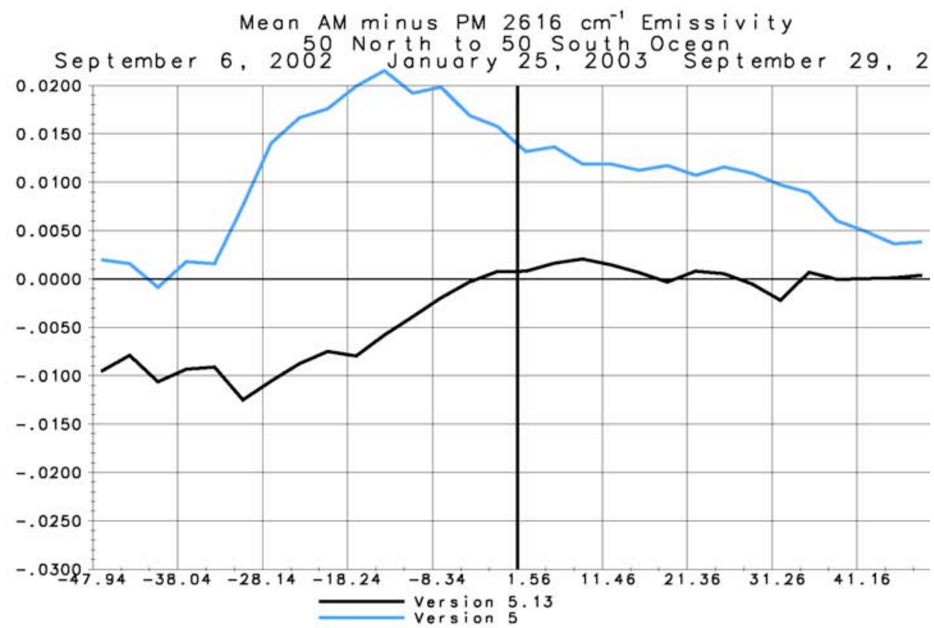
Mean AM minus PM 950 cm^{-1} Emissivity
50 North to 50 South Ocean
September 6, 2002 January 25, 2003 September 29, 2004
0.0200
0.0150
0.0100
0.0050
0.0000
-.0050
-.0100
-.0150
-.0200
-.0250
-.0300
-47.94 -38.04 -28.14 -18.24 -8.34 1.56 11.46 21.36 31.26 41.16
Version 5.13
Version 5



Mean AM minus PM 1050 cm^{-1} Emissivity
50 North to 50 South Ocean
September 6, 2002 January 25, 2003 September 29, 2
0.0200
0.0150
0.0100
0.0050
0.0000
-.0050
-.0100
-.0150
-.0200
-.0250
-.0300
-47.94 -38.04 -28.14 -18.24 -8.34 1.56 11.46 21.36 31.26 41.16
Version 5.13
Version 5



Mean AM minus PM 2400 cm^{-1} Emissivity
50 North to 50 South Ocean
September 6, 2002 January 25, 2003 September 29, 2004
0.0200
0.0150
0.0100
0.0050
0.0000
-.0050
-.0100
-.0150
-.0200
-.0250
-.0300
-47.94 -38.04 -28.14 -18.24 -8.34 1.56 11.46 21.36 31.26 41.16
Version 5.13
Version 5



Mean AM minus PM 2616 cm^{-1} Emissivity
50 North to 50 South Ocean
September 6, 2002 January 25, 2003 September 29, 2
0.0200
0.0150
0.0100
0.0050
0.0000
-.0050
-.0100
-.0150
-.0200
-.0250
-.0300
-47.94 -38.04 -28.14 -18.24 -8.34 1.56 11.46 21.36 31.26 41.16
Version 5.13
Version 5

Metrics for Improved Ocean Spectral Emissivity

950 cm^{-1}	$\varepsilon_N(0)-\varepsilon_{MAS}0$	$\varepsilon_D(0)-\varepsilon_{MAS}0$	MAX $\lvert\varepsilon_N(\Theta)-\varepsilon_D(\Theta)\rvert$	MAX $\lvert\varepsilon_D(\Theta)-\varepsilon_D(-\Theta)\rvert$
Version 5	-.007	- .006	.009	.015
Version 5.13	-.001	- .001	.001	.001
Version 6 Goal	-.002	- .002	.006	.010
2400 cm^{-1}	$\varepsilon_N(0)-\varepsilon_{MAS}0$	$\varepsilon_D(0)-\varepsilon_{MAS}0$	MAX $\lvert\varepsilon_N(\Theta)-\varepsilon_D(\Theta)\rvert$	MAX $\lvert\varepsilon_D(\Theta)-\varepsilon_D(-\Theta)\rvert$
Version 5	-.009	- .023	.022	.011
Version 5.13	-.008	-.009	.013 (mostly < .005)	.005
Version 6 Goal	-.005	-0.10	.008	.006

Version 5.13 performance exceeds all emissivity metrics at 950 cm^{-1}
Version 5.13 performance does not meet all metrics at 2400 cm^{-1}

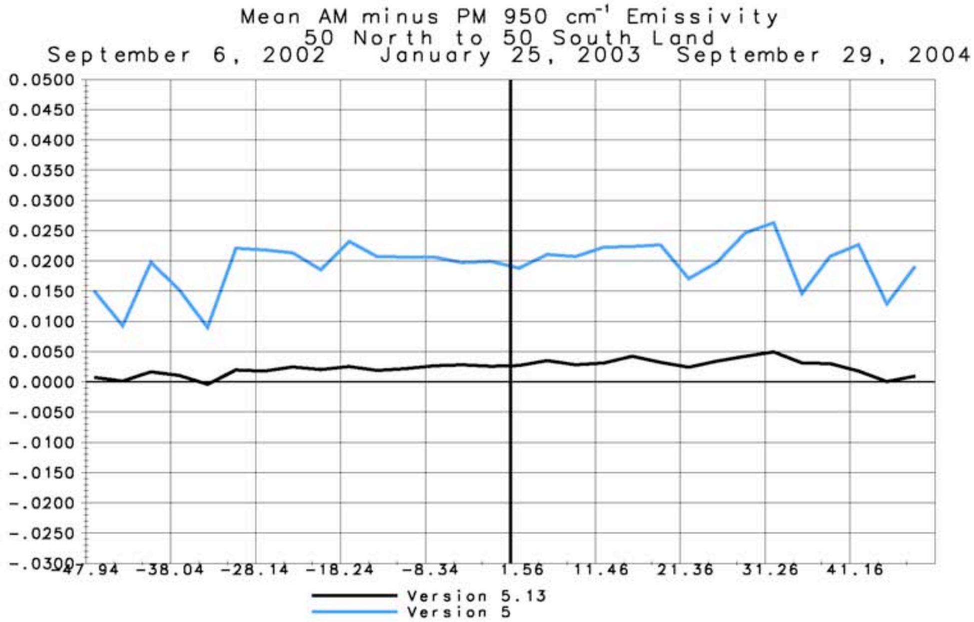
Assessment of Potential Improvements over Land

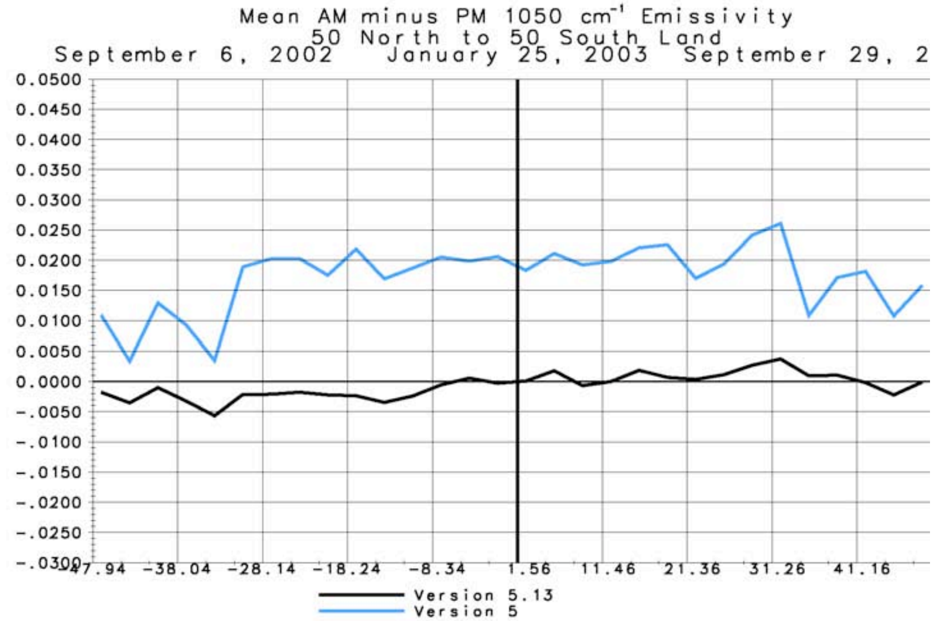
There is no accurate measure of land surface skin temperature or spectral emissivity

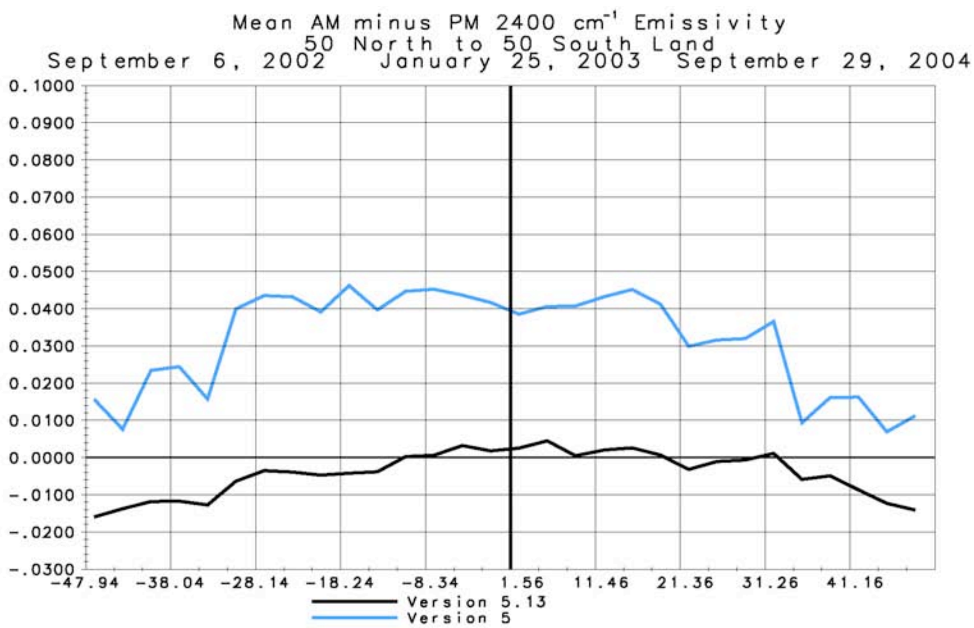
Improvements in emissivity are indicated by smaller day/night difference of angular mean results

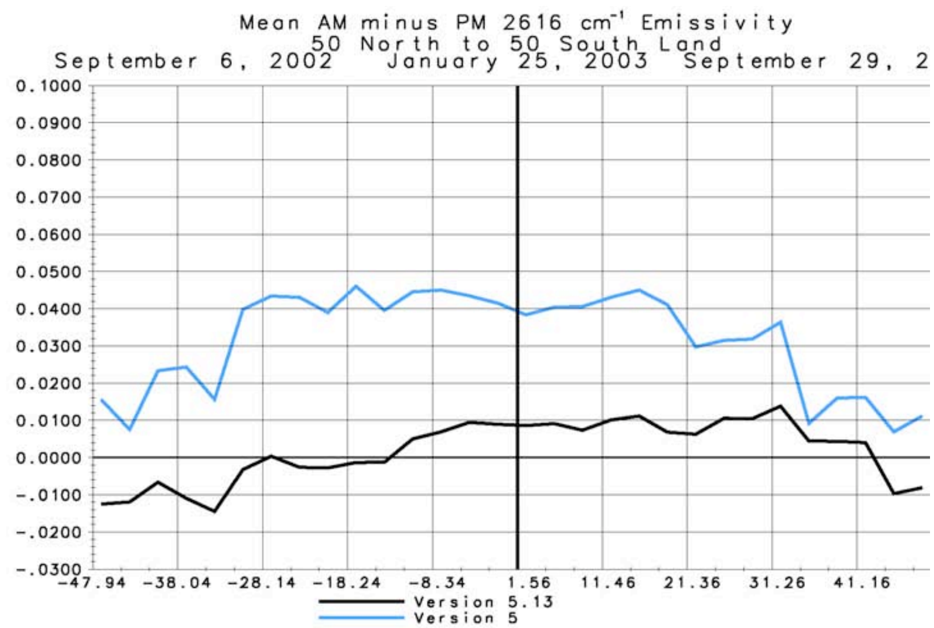
Indirect assessment of improved T_s and ε_ν

More accurate total O_3 - affected by emissivity near 1050 cm^{-1}

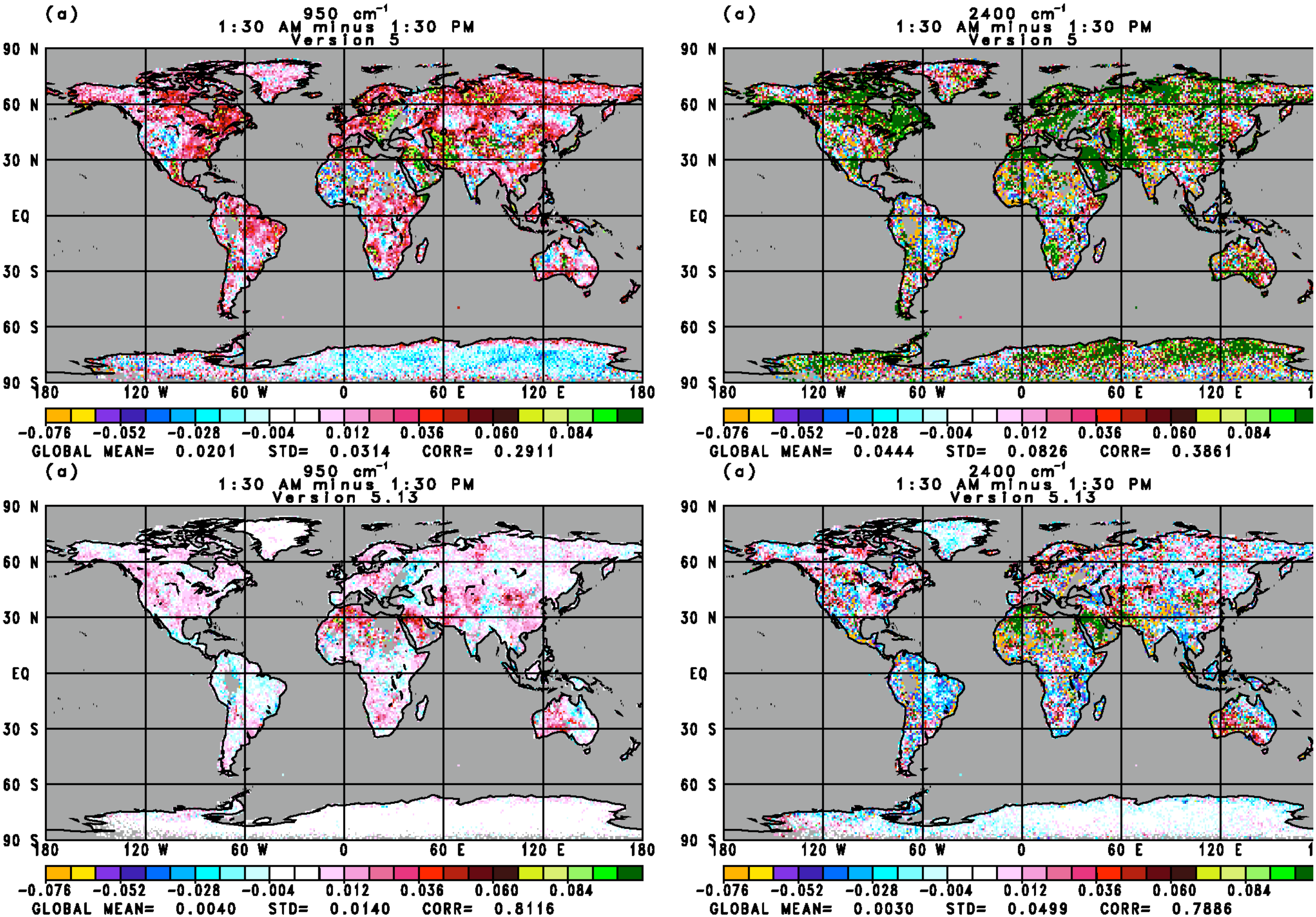

Mean AM minus PM 950 cm-1 Emissivity
50 North to 50 South Land
September 6, 2002 January 25, 2003 September 29, 2004
Version 5.13
Version 5

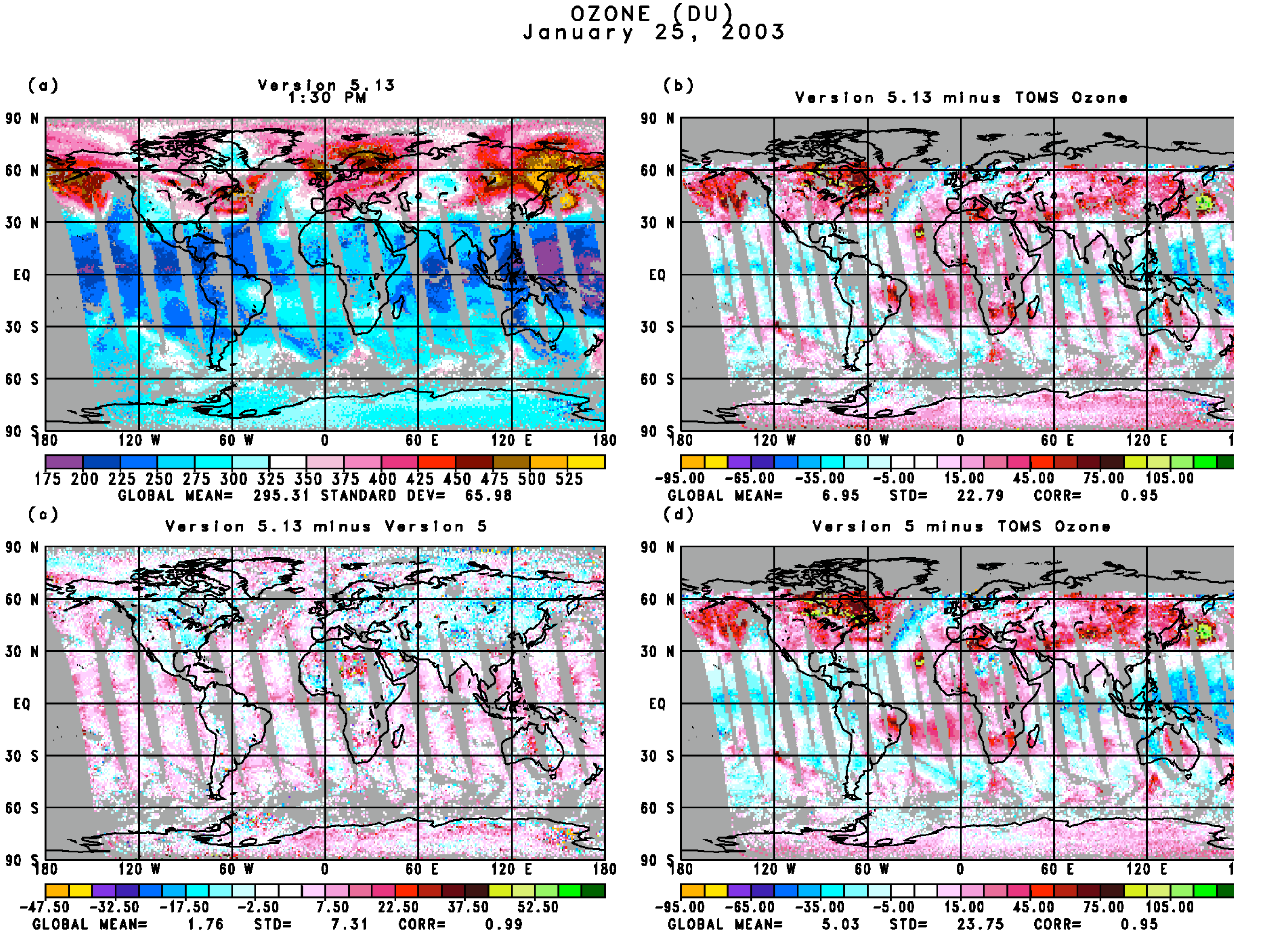

Mean AM minus PM 1050 cm-1 Emissivity
50 North to 50 South Land
September 6, 2002 January 25, 2003 September 29, 2
Version 5.13
Version 5


Mean AM minus PM 2400 cm-1 Emissivity
50 North to 50 South Land
September 6, 2002 January 25, 2003 September 29, 2004
Version 5.13
Version 5


Mean AM minus PM 2616 cm-1 Emissivity
50 North to 50 South Land
September 6, 2002 January 25, 2003 September 29, 2
Version 5.13
Version 5

September 6, 2002, January 25, 2003, and September 29, 2004
AIRS IR Emissivity




OZONE (DU)
January 25, 2003
(a)
Version 5.13
1:30 PM
90 N
60 N
30 N
EQ
30 S
60 S
90 S
180
120 W
60 W
0
60 E
120 E
180
175 200 225 250 275 300 325 350 375 400 425 450 475 500 525
GLOBAL MEAN= 295.31 STANDARD DEV= 65.98
(b)
Version 5.13 minus TOMS Ozone
-95.00 -65.00 -35.00 -5.00 15.00 45.00 75.00 105.00
GLOBAL MEAN= 6.95 STD= 22.79 CORR= 0.95
(c)
Version 5.13 minus Version 5
-47.50 -32.50 -17.50 -2.50 7.50 22.50 37.50 52.50
GLOBAL MEAN= 1.76 STD= 7.31 CORR= 0.99
(d)
Version 5 minus TOMS Ozone
-95.00 -65.00 -35.00 -5.00 15.00 45.00 75.00 105.00
GLOBAL MEAN= 5.03 STD= 23.75 CORR= 0.95

Proposed Further Improvements for Version 6

*Higher spatial resolution retrievals - Thomas Hearty

*Further improvements in surface parameter retrieval - John Blaisdell

*Implementation of improved OLR RTA (AER?) - Gyula Molnar

Further improvements in T(p), q(p), O_3(p) retrievals - especially over land - John Blaisdell

Improved stability of cloud cover parameter retrievals - Thomas Hearty, John Blaisdell

Improvements to quality control and level-3 gridding – Lena Iredell

Thresholds, QC flags, treatment of polar regions and coastlines

Note – All improvements will be implemented and evaluated in parallel in an AIRS only system

*Highest priority

Higher Spatial Resolution Retrievals

Version 5.13 generates a single retrieval per AMSU FOR (3x3 array of AIRS FOV's)

Individual cloud fractions are calculated and written out for each AIRS FOV

Proposed approach generates one retrieval for a 1 (cross track) x 3 (along track) array of AIRS FOV's

Lat, lon assigned to center of 1x3 array

Potential benefit

Area is smaller: 13 x 45 km at nadir, 33 x 70 km at end of scan, vs. 45 x 45 km and 100 x 70 km

Therefore, surface and moisture homogeneity should be better

Allows for better cloud clearing and retrievals

Improvement should be greatest over land, especially at large zenith angles

Potential benefit remains to be demonstrated.

Proposed High Spatial Resolution Methodology

Incorporation of 1 x 3 cloud clearing and retrieval scheme to be done only in physical retrieval

Cloudy regression and regression steps will use 3 x 3 array of spots as done now

Three options of how to proceed

1) Perform and output 3 sets of final product retrievals per AMSU FOR

    Increases current data output and processing time roughly threefold

2) Perform 3 sets of retrievals and output results for the "best" retrieval - based on error estimates

    Increases processing time threefold - data output unchanged

3) Generate cloud cleared radiances for each 1 x 3 array

    Perform retrieval only on the 1 x 3 array that looks "most promising" - lowest A_{eff}?

    Retrieval will be assigned to lat-lon of the center of the 1 x 3 array

    Keeps processing time and data rate unchanged

We recommend option 3) for Version 6 if results are better than obtained with 3 x 3 retrievals

9 sets of cloud fractions will be generated in all options, as done currently

Further Improved Surface Parameter Retrievals

Surface parameter retrieval step

Currently solves for T_s and coefficients of 2 SW emissivity and 2 SW reflectivity perturbation functions

Both sets of short wave hinge points are at 2450 cm^{-1} and 2620 cm^{-1}

This means spectral perturbation function is constant for $\nu < 2450$ cm^{-1}

We will examine use of 3 emissivity and/or 3 reflectivity functions

Lowest frequency hinge point near 2400 cm^{-1} if practical

Important for T(p) retrieval step

(LW) spectral emissivity step

Keeps T_s fixed

Currently solves for coefficients of three LW spectral emissivity function

Hinge points are set at 870 cm^{-1}, 980 cm^{-1}, and 1090 cm^{-1}

This step is very stable - coefficients of more functions are easily solved for

We will assess adding more functions

Hinge points near 760 cm^{-1} and 1130 cm^{-1}

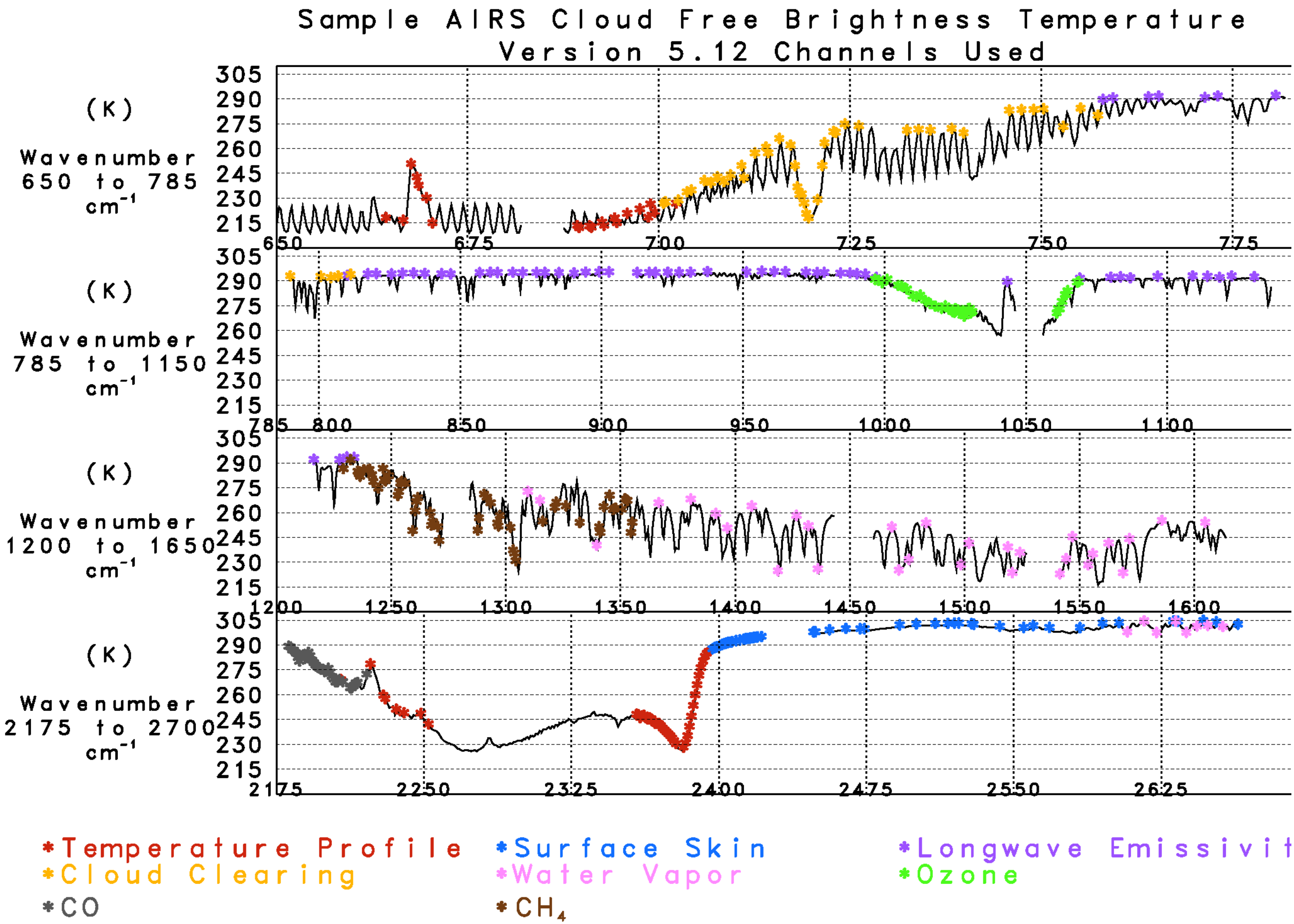
Important for cloud clearing

Hinge point near 1230 cm^{-1}

Important for CH_4 and H_2O

Hinge point near 2180 cm^{-1} (this is questionable)

Potentially important for CO



Sample AIRS Cloud Free Brightness Temperature
Version 5.12 Channels Used
(K)
Wavenumber 650 to 785 cm^{-1}
Wavenumber 785 to 1150 cm^{-1}
Wavenumber 1200 to 1650 cm^{-1}
Wavenumber 2175 to 2700 cm^{-1}
305
290
275
260
245
230
215
650
675
700
725
750
775
785
800
850
900
950
1000
1050
1100
1200
1250
1300
1350
1400
1450
1500
1550
1600
2175
2250
2325
2400
2475
2550
2625
*Temperature Profile
*Surface Skin
*Longwave Emissivit
*Cloud Clearing
*Water Vapor
*Ozone
*CO
*CH_4

Improvements to Temperature Profile Retrieval

- High spatial resolution retrievals should (may) improve retrievals, especially over land

- More research will be done on channels used in T(p) retrievals
  - Version 5.13 uses 12 H_2O sounding channels between 1238 cm^{-1} and 1382 cm^{-1} in second pass
  - Water vapor is assumed well known by second pass
  - A very recent experiment removing these channels from second pass T(p) degraded results
  - Use of these channels will be optimized further
  - We will also study better use of channels near 2240 cm^{-1}

- We will examine using window channels over land in second pass cloud clearing
  - Currently, window channels are used for cloud clearing over ocean only
  - Potentially feasible over land if a good spectral emissivity has been obtained
    - High spatial resolution retrievals should help as well
  - This may significantly improve accuracy and yield of T(p) over land in lower troposphere

Improvements in $H_2O(p)$ and $O_3(p)$ Retrievals

Perform channel optimization studies for each step

Assess potential benefit of a second pass $H_2O(p)$ and $O_3(p)$ retrieval

- Second pass should have better cloud cleared radiances, especially over land
- Second pass should have better local spectral emissivities

Results of proposed improvements will be evaluated and shown periodically at Net-meetings

Questions

- When do we need to agree on a final Version 6 configuration
- When should John install Version 5.13, perhaps with minor modifications, for testing at JPL

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